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(54) Title: CLONING USING DONOR NUCLEI FROM NON-SERUM STARVED, DIFFERENTIATED CELLS (57) Abstract An improved method of nuclear transfer involving the transplantation of donor differentiated cell nuclei from non-serum starved cells into enucleated oocytes of the same species as the donor cell is provided. The resultant nuclear transfer units are useful for multiplication of genotypes and transgenic genotypes by the production of fetuses and offspring, and for production of isogenic CICM cells, including human isogenic embryonic or stem cells. Production of genetically engineered or transgenic mammalian embryos, fetuses and offspring is facilitated by the present method since the differentiated cell source of the donor nuclei can be genetically modified and clonally propagated.		

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**CLONING USING DONOR NUCLEI FROM
NON-SERUM STARVED DIFFERENTIATED CELLS**

1. FIELD OF THE INVENTION

The present invention relates to cloning procedures in which cell nuclei derived from non-serum starved, differentiated, mammalian cells are transplanted into enucleated mammalian oocytes of the same species as the donor nuclei. The nuclei are reprogrammed to direct the development of cloned embryos, which can then be transferred into recipient females to produce fetuses and offspring, or used to produce cultured inner cell mass cells (CICM). The cloned embryos can also be combined with fertilized embryos to produce chimeric embryos, fetuses and/or offspring.

2. BACKGROUND OF THE INVENTION

The use of ungulate inner cell mass (ICM) cells for nuclear transplantation has been reported. For example, Collas et al., *Mol. Reprod. Dev.*, 38:264-267 (1994) discloses nuclear transplantation of bovine ICMs by microinjection of the lysed donor cells into enucleated mature oocytes.

Collas et al. disclosed culturing of embryos *in vitro* for seven days to produce fifteen blastocysts which, upon transferral into bovine recipients, resulted in four pregnancies and two births. Also, Keefer et al., *Biol. Reprod.*, 50:935-939 (1994), disclosed the use of bovine ICM cells as donor nuclei in nuclear transfer procedures, to produce blastocysts which, upon transplantation into bovine recipients, resulted in several live offspring. Further, Sims et al., *Proc. Natl. Acad. Sci., USA*, 90:6143-6147 (1993), disclosed the production of calves by transfer of nuclei from short-term *in vitro* cultured bovine ICM cells into enucleated mature oocytes.

The production of live lambs following nuclear transfer of cultured embryonic disc cells has also been reported (Campbell et al., *Nature*,

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380:64-68 (1996)). Still further, the use of bovine pluripotent embryonic cells in nuclear transfer and the production of chimeric fetuses has been reported (Stice et al., *Biol. Reprod.*, 54:100-110 (1996); Collas et al, *Mol. Reprod. Dev.*, 38:264-267 (1994)). Collas et al demonstrated that

5 granulosa cells (adult cells) could be used in a bovine cloning procedure to produce embryos. However, there was no demonstration of development past early embryonic stages (blastocyst stage). Also, granulosa cells are not easily cultured and are only obtainable from females. Collas et al did not attempt to propagate the granulosa cells in culture or try to genetically

10 modify those cells. Wilmut et al (*Nature*, 355:810-813 (1997)) produced nuclear transfer sheep offspring derived from fetal fibroblast cells, and one offspring from a cell derived from an adult sheep.

There also exist problems in the area of producing transgenic mammals. By current methods, heterologous DNA is introduced into either

15 early embryos or embryonic cell lines that differentiate into various cell types in the fetus and eventually develop into a transgenic animal. However, many early embryos are required to produce one transgenic animal and, thus, this procedure is very inefficient. Also, there is no simple and efficient method of selecting for a transgenic embryo before going

20 through the time and expense of putting the embryos into surrogate females. In addition, gene targeting techniques cannot be easily accomplished with early embryo transgenic procedures.

Embryonic stem cells in mice have enabled researchers to select for transgenic cells and perform gene targeting. This allows more genetic

25 engineering than is possible with other transgenic techniques. However, embryonic stem cell lines and other embryonic cell lines must be maintained in an undifferentiated state that requires feeder layers and/or the addition of cytokines to media. Even if these precautions are followed, these cells often undergo spontaneous differentiation and cannot be used to produce

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transgenic offspring by currently available methods. Also, some embryonic cell lines have to be propagated in a way that is not conducive to gene targeting procedures.

Methods for deriving embryonic stem (ES) cell lines *in vitro* from
5 early preimplantation mouse embryos are well known. (See, e.g., Evans et al., *Nature*, 29:154-156 (1981); Martin, *Proc. Natl. Acad. Sci., USA*, 78:7634-7638 (1981)). ES cells can be passaged in an undifferentiated state, provided that a feeder layer of fibroblast cells (Evans et al., *Id.*) or a differentiation inhibiting source (Smith et al., *Dev. Biol.*, 121:1-9 (1987)) is
10 present.

ES cells have been previously reported to possess numerous applications. For example, it has been reported that ES cells can be used as an *in vitro* model for differentiation, especially for the study of genes which are involved in the regulation of early development. Mouse ES cells can
15 give rise to germline chimeras when introduced into preimplantation mouse embryos, thus demonstrating their pluripotency (Bradley et al., *Nature*, 309:255-256 (1984)).

In view of their ability to transfer their genome to the next generation, ES cells have potential utility for germline manipulation of
20 livestock animals by using ES cells with or without a desired genetic modification. Moreover, in the case of livestock animals, e.g., ungulates, nuclei from like preimplantation livestock embryos support the development of enucleated oocytes to term (Smith et al., *Biol. Reprod.*, 40:1027-1035 (1989); and Keefer et al., *Biol. Reprod.*, 50:935-939 (1994)). This is in
25 contrast to nuclei from mouse embryos which beyond the eight-cell stage after transfer reportedly do not support the development of enucleated oocytes (Cheong et al., *Biol. Reprod.*, 48:958 (1993)). Therefore, ES cells from livestock animals are highly desirable because they may provide a potential source of totipotent donor nuclei, genetically manipulated or

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otherwise, for nuclear transfer procedures.

Some research groups have reported the isolation of purportedly pluripotent embryonic cell lines. For example, Notarianni et al., *J. Reprod. Fert. Suppl.*, 43:255-260 (1991), reports the establishment of purportedly stable, pluripotent cell lines from pig and sheep blastocysts which exhibit some morphological and growth characteristics similar to that of cells in primary cultures of inner cell masses isolated immunosurgically from sheep blastocysts. Also, Notarianni et al., *J. Reprod. Fert. Suppl.*, 41:51-56 (1990) discloses maintenance and differentiation in culture of putative pluripotential embryonic cell lines from pig blastocysts. Gerfen et al., *Anim. Biotech*, 6(1):1-14 (1995) discloses the isolation of embryonic cell lines from porcine blastocysts. These cells are stably maintained in mouse embryonic fibroblast feeder layers without the use of conditioned medium, and reportedly differentiate into several different cell types during culture.

Further, Saito et al., *Roux's Arch. Dev. Biol.*, 201:134-141 (1992) reports cultured, bovine embryonic stem cell-like cell lines which survived three passages, but were lost after the fourth passage. Handyside et al., *Roux's Arch. Dev. Biol.*, 196:185-190 (1987) discloses culturing of immunosurgically isolated inner cell masses of sheep embryos under conditions which allow for the isolation of mouse ES cell lines derived from mouse ICMs. Handyside et al. reports that under such conditions, the sheep ICMs attach, spread, and develop areas of both ES cell-like and endoderm-like cells, but that after prolonged culture only endoderm-like cells are evident.

Recently, Cherny et al., *Theriogenology*, 41:175 (1994) reported purportedly pluripotent bovine primordial germ cell-derived cell lines maintained in long-term culture. These cells, after approximately seven days in culture, produced ES-like colonies which stained positive for alkaline phosphatase (AP), exhibited the ability to form embryoid bodies, and

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spontaneously differentiated into at least two different cell types. These cells also reportedly expressed mRNA for the transcription factors OCT4, OCT6 and HES1, a pattern of homeobox genes which is believed to be expressed by ES cells exclusively.

5 Also recently, Campbell et al., *Nature*, 380:64-68 (1996) reported the production of live lambs following nuclear transfer of cultured embryonic disc (ED) cells from day nine ovine embryos cultured under conditions which promote the isolation of ES cell lines in the mouse. The authors concluded that ED cells from day nine ovine embryos are totipotent
10 by nuclear transfer and that totipotency is maintained in culture.

Van Stekelenburg-Hamers et al., *Mol. Reprod. Dev.*, 40:444-454 (1995), reported the isolation and characterization of purportedly permanent cell lines from inner cell mass cells of bovine blastocysts. The authors isolated and cultured ICMs from 8 or 9 day bovine blastocysts under
15 different conditions to determine which feeder cells and culture media are most efficient in supporting the attachment and outgrowth of bovine ICM cells. They concluded that the attachment and outgrowth of cultured ICM cells is enhanced by the use of STO (mouse fibroblast) feeder cells (instead of bovine uterus epithelial cells) and by the use of charcoal-stripped serum
20 (rather than normal serum) to supplement the culture medium. Van Stekelenburg et al reported, however, that their cell lines resembled epithelial cells more than pluripotent ICM cells.

Smith et al., WO 94/24274, published October 27, 1994, Evans et al, WO 90/03432, published April 5, 1990, and Wheeler et al, WO
25 94/26889, published November 24, 1994, report the isolation, selection and propagation of animal stem cells which purportedly may be used to obtain transgenic animals. Evans et al. also reported the derivation of purportedly pluripotent embryonic stem cells from porcine and bovine species which assertedly are useful for the production of transgenic

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animals. Further, Wheeler et al, WO 94/26884, published November 24, 1994, disclosed embryonic stem cells which are assertedly useful for the manufacture of chimeric and transgenic ungulates.

Thus, based on the foregoing, it is evident that many groups have attempted to produce ES cell lines, e.g., because of their potential application in the production of cloned or transgenic embryos and in nuclear transplantation.

Notwithstanding what has previously been reported in the literature, there exists a need for improved methods of cloning mammalian cells.

10

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide novel and improved methods for producing cloned mammals (e.g., embryos, fetuses and offspring).

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It is a more specific object of the invention to provide a novel method for cloning mammals which involves transplantation of the nucleus of a non-serum starved, differentiated mammalian cell into an enucleated oocyte of the same species.

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It is another object of the invention to provide a method for multiplying adult mammals having proven genetic superiority or other desirable traits.

It is another object of the invention to provide an improved method for producing genetically engineered or transgenic mammals (i.e., embryos, fetuses, offspring). The invention also provides genetically engineered or transgenic mammals made by such a method.

25

It is a more specific object of the invention to provide a method for producing genetically engineered or transgenic mammals by which a desired DNA sequence is inserted, removed or modified in a differentiated

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mammalian cell or cell nucleus prior to use of that differentiated cell or cell nucleus for formation of a NT unit. The invention also provides genetically engineered or transgenic mammals made by such a method.

It is another object of the invention to provide a method for
5 producing genetically engineered or transgenic mammals by transplantation of the nucleus of a non-serum starved, transgenic, differentiated cell into an enucleated oocyte of the same species as the differentiated cell. The invention also provides genetically engineered or transgenic mammals made by such a method.

10 It is another object of the invention to provide a novel method for producing mammalian CICM cells which involves transplantation of a nucleus of a non-serum starved, differentiated cell into an enucleated oocyte of the same species as the differentiated cell.

It is another object of the invention to provide CICM cells produced
15 by transplantation of the nucleus of a non-serum starved, differentiated mammalian cell into an enucleated oocyte of the same species as the differentiated cell.

It is a more specific object of the invention to provide a method for producing human CICM cells which involves transplantation of nuclei of a
20 non-serum starved, human cell, e.g., a human adult cell, into an enucleated human oocyte.

It is another object of the invention to use such CICM cells for therapy or diagnosis.

It is a specific object of the invention to use such CICM cells,
25 including human and ungulate CICM cells, for treatment or diagnosis of any disease wherein cell, tissue or organ transplantation is therapeutically or diagnostically beneficial. The CICM cells may be used within the same species or across species.

It is another object of the invention to use cells or tissues derived

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from NT embryos, fetuses or offspring, including human and ungulate tissues, for treatment or diagnosis of any disease or injury wherein cell, tissue or organ transplantation is therapeutically or diagnostically beneficial. Such diseases and injuries include Parkinson's, Huntington's, Alzheimer's, 5 ALS, spinal cord injuries, multiple sclerosis, muscular dystrophy, diabetes, liver diseases, heart disease, cartilage replacement, burns, vascular diseases, urinary tract diseases, as well as for the treatment of immune defects, bone marrow transplantation, cancer, among other diseases. The tissues may be used within the same species or across species.

10 It is another specific object of the invention to use the CICM cells produced according to the invention for the production of differentiated cells, tissues or organs.

It is a more specific object of the invention to use the human CICM cells produced according to the invention for the production of 15 differentiated human cells, tissues or organs.

It is another specific object of the invention to use the CICM cells produced according to the invention *in vitro*, e.g. for study of cell differentiation and for assay purposes, e.g. for drug studies.

It is another object of the invention to provide improved methods of 20 transplantation therapy, comprising the usage of isogenic or syngenic cells, tissues or organs produced from the CICM cells produced according to the invention. Such therapies include by way of example treatment of diseases and injuries including Parkinson's, Huntington's, Alzheimer's, ALS, spinal cord injuries, multiple sclerosis, muscular dystrophy, diabetes, liver 25 diseases, heart disease, cartilage replacement, burns, vascular diseases, urinary tract diseases, as well as for the treatment of immune defects, bone marrow transplantation, cancer, among other diseases.

It is another object of the invention to provide genetically engineered or transgenic CICM cells produced by inserting, removing or modifying a

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desired DNA sequence in a differentiated mammalian cell or cell nucleus prior to use of that differentiated cell or cell nucleus for formation of a NT unit.

It is another object of the invention to use the transgenic or
5 genetically engineered CICM cells produced according to the invention for gene therapy, in particular for the treatment and/or prevention of the diseases and injuries identified, *supra*.

It is another object of the invention to use the CICM cells produced according to the invention or transgenic or genetically engineered CICM
10 cells produced according to the invention as nuclear donors for nuclear transplantation.

Thus, in one aspect, the present invention provides a method for cloning a mammal (e.g., embryos, fetuses, offspring). The method comprises:

- 15 (i) inserting a desired non-serum starved, differentiated mammalian cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated cell or cell nucleus, under conditions suitable for the formation of a nuclear transfer (NT) unit;
- (ii) activating the resultant nuclear transfer unit; and
- 20 (iii) transferring said cultured NT unit to a host mammal such that the NT unit develops into a fetus.

Preferably, the activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

The cells, tissues and/or organs of the fetus are advantageously used
25 in the area of cell, tissue and/or organ transplantation.

The present invention also includes a method of cloning a genetically engineered or transgenic mammal, by which a desired DNA sequence is inserted, removed or modified in the differentiated mammalian cell or cell nucleus prior to insertion of the differentiated mammalian cell or cell

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nucleus into the enucleated oocyte.

Also provided by the present invention are mammals obtained according to the above method, and offspring of those mammals.

The present invention is preferably used for cloning ungulates.

5 In another aspect, the present invention provides a method for producing CICM cells. The method comprises:

- (i) inserting a desired non-serum starved, differentiated mammalian cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated cell or cell nucleus, under conditions
10 suitable for the formation of a nuclear transfer (NT) unit;
- (ii) activating the resultant nuclear transfer unit; and
- (iii) culturing cells obtained from said cultured NT unit to obtain CICM cells.

15 Preferably, the activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

The CICM cells are advantageously used in the area of cell, tissue and organ transplantation.

20 With the foregoing and other objects, advantages and features of the invention that will become hereinafter apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the preferred embodiments of the invention and to the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

25 The present invention provides improved procedures for cloning mammals by nuclear transfer or nuclear transplantation. In the subject application, nuclear transfer or nuclear transplantation or NT are used interchangeably.

According to the invention, cell nuclei derived from non-serum

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starved, differentiated mammalian cells are transplanted into enucleated mammalian oocytes of the same species as the donor nuclei. The nuclei are reprogrammed to direct the development of cloned embryos, which can then be transferred into recipient females to produce fetuses and offspring, or used to produce CICM cells. The cloned embryos can also be combined with fertilized embryos to produce chimeric embryos, fetuses and/or offspring.

Prior art methods have used embryonic cell types in cloning procedures. This includes work by Campbell et al (*Nature*, 380:64-68, 1996) and Stice et al (*Biol. Reprod.*, 54:100-110, 1996). In both of those studies, embryonic cell lines were derived from embryos of less than 10 days of gestation. In both studies, the cells were maintained on a feeder layer to prevent overt differentiation of the donor cell to be used in the cloning procedure. The present invention has been found to be effective using either fetal or adult cells.

It was unexpected that cloned embryos with fetal or adult donor nuclei could develop to advanced embryonic and fetal stages. The scientific dogma has been that only early embryonic cell types could direct this type of development. It was unexpected that a large number of cloned embryos could be produced from fetal or adult cells. Also, the fact that new transgenic embryonic cell lines could be readily derived from transgenic cloned embryos was unexpected.

Adult cells and fetal fibroblast cells from a sheep have purportedly been used to produce a sheep offspring (Wilmot et al, 1997). In that study, however, it was emphasized that the use of a serum starved, nucleus donor cell in the quiescent state was important for success of the Wilmot cloning method. No such requirement for serum starvation or quiescence exists for the present invention. On the contrary, cloning is achieved using non-serum starved, differentiated mammalian cells.

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Moreover, cloning efficiency according to the present invention can be the same regardless of whether fetal or adult donor cells are used, whereas Wilmut et al (1997) reported that lower cloning efficiency was achieved with adult donor cells.

5 Thus, according to the present invention, multiplication of superior genotypes of mammals, including ungulates, is possible. This will allow the multiplication of adult animals with proven genetic superiority or other desirable traits. Progress will be accelerated, for example, in many important ungulate species. By the present invention, there are potentially
10 billions of fetal or adult cells that can be harvested and used in the cloning procedure. This will potentially result in many identical offspring in a short period.

 There has also been speculation that the Wilmut et al method will lead to the generation of transgenic animals (see MacQuitty, *Nature*
15 *Biotech.*, 15:294 (1997)). However, there is no reason to assume, for example, that nuclei from adult cells that have been transfected with exogenous DNA will be able to survive the process of nuclear transfer. In this regard, it is known that the properties of mouse embryonic stem (ES) cells are altered by *in vitro* manipulation such that their ability to form viable
20 chimeric embryos is effected. Therefore, prior to the present invention, the cloning of transgenic animals could not have been predicted.

 The present invention allows simplification of transgenic procedures by working with a cell source that can be clonally propagated. This eliminates the need to maintain the cells in an undifferentiated state, thus,
25 genetic modifications, both random integration and gene targeting, are more easily accomplished. Also by combining nuclear transfer with the ability to modify and select for these cells *in vitro*, this procedure is more efficient than previous transgenic embryo techniques. According to the present invention, these cells can be clonally propagated without cytokines,

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conditioned media and/or feeder layers, further simplifying and facilitating the transgenic procedure. When transfected cells are used in cloning procedures according to the invention, transgenic embryos are produced which can develop into fetuses and offspring. Also, these transgenic
5 cloned embryos can be used to produce CICM cell lines or other embryonic cell lines. Therefore, the present invention eliminates the need to derive and maintain in vitro an undifferentiated cell line that is conducive to genetic engineering techniques.

The present invention can also be used to produce CICM cells,
10 fetuses or offspring which can be used, for example, in cell, tissue and organ transplantation. By taking a fetal or adult cell from an animal and using it in the cloning procedure a variety of cells, tissues and possibly organs can be obtained from cloned fetuses as they develop through organogenesis. Cells, tissues, and organs can be isolated from cloned
15 offspring as well. This process can provide a source of "materials" for many medical and veterinary therapies including cell and gene therapy. If the cells are transferred back into the animal in which the cells were derived, then immunological rejection is averted. Also, because many cell types can be isolated from these clones, other methodologies such as
20 hematopoietic chimerism can be used to avoid immunological rejection among animals of the same species as well as between species.

Thus, in one aspect, the present invention provides a method for cloning a mammal. In general, the mammal will be produced by a nuclear transfer process comprising the following steps:

- 25 (i) obtaining desired non-serum starved, differentiated mammalian cells to be used as a source of donor nuclei;
- (ii) obtaining oocytes from a mammal of the same species as the cells which are the source of donor nuclei;
- (iii) enucleating said oocytes;

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(iv) transferring the desired differentiated cell or cell nucleus into the enucleated oocyte, e.g., by fusion or injection, to form NT units;

(v) activating the resultant NT unit; and

(vi) transferring said cultured NT unit to a host mammal such that the NT unit develops into a fetus.

Preferably, the activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

The present invention also includes a method of cloning a genetically engineered or transgenic mammal, by which a desired DNA sequence is inserted, removed or modified in the differentiated mammalian cell or cell nucleus prior to insertion of the differentiated mammalian cell or cell nucleus into the enucleated oocyte.

Also provided by the present invention are mammals obtained according to the above method, and offspring of those mammals. The present invention is preferably used for cloning ungulates.

The present invention further provides for the use of NT fetuses and NT and chimeric offspring in the area of cell, tissue and organ transplantation.

In another aspect, the present invention provides a method for producing CICM cells. The method comprises:

- (i) inserting a desired non-serum starved, differentiated mammalian cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated cell or cell nucleus, under conditions suitable for the formation of a nuclear transfer (NT) unit;
- (ii) activating the resultant nuclear transfer unit; and
- (iii) culturing cells obtained from said cultured NT unit to obtain CICM cells.

Preferably, the activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

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The CICM cells are advantageously used in the area of cell, tissue and organ transplantation, or in the production of fetuses or offspring, including transgenic fetuses or offspring.

As used herein, a fetus is the unborn young of a viviporous animal
5 after it has taken form in the uterus. Thus, in cows the fetal stage occurs from 35 days after conception until birth. In pigs, the fetal stage occurs from 30 days after conception until birth. A mammal is an adult from birth until death.

Preferably, the NT units will be cultured to a size of at least 2 to 400
10 cells, preferably 4 to 128 cells, and most preferably to a size of at least about 50 cells.

Nuclear transfer techniques or nuclear transplantation techniques are known in the literature and are described in many of the references cited in the Background of the Invention. See, in particular, Campbell et al,
15 *Theriogenology*, 43:181 (1995); Collas et al, *Mol. Report Dev.*, 38:264-267 (1994); Keefer et al, *Biol. Reprod.*, 50:935-939 (1994); Sims et al, *Proc. Natl. Acad. Sci., USA*, 90:6143-6147 (1993); WO 94/26884; WO 94/24274, and WO 90/03432, which are incorporated by reference in their entirety herein. Also, U.S. Patent Nos. 4,944,384 and 5,057,420 describe
20 procedures for bovine nuclear transplantation.

Differentiated refers to cells having a different character or function from the surrounding structures or from the cell of origin. Differentiated mammalian cells are those cells which are past the early embryonic stage. More particularly, the differentiated cells are those from at least past the
25 embryonic disc stage (day 10 of bovine embryogenesis). The differentiated cells may be derived from ectoderm, mesoderm or endoderm.

Mammalian cells, including human cells, may be obtained by well known methods. Mammalian cells useful in the present invention include, by way of example, epithelial cells, neural cells, epidermal cells,

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keratinocytes, hematopoietic cells, melanocytes, chondrocytes, lymphocytes (B and T lymphocytes), erythrocytes, macrophages, monocytes, mononuclear cells, fibroblasts, cardiac muscle cells, and other muscle cells, etc. Moreover, the mammalian cells used for nuclear transfer
5 may be obtained from different organs, e.g., skin, lung, pancreas, liver, stomach, intestine, heart, reproductive organs, bladder, kidney, urethra and other urinary organs, etc. These are just examples of suitable donor cells. Suitable donor cells, i.e., cells useful in the subject invention, may be obtained from any cell or organ of the body. This includes all somatic or
10 germ cells.

Fibroblast cells are an ideal cell type because they can be obtained from developing fetuses and adult animals in large quantities. Fibroblast cells are differentiated somewhat and, thus, were previously considered a poor cell type to use in cloning procedures. Importantly, these cells can be
15 easily propagated in vitro with a rapid doubling time and can be clonally propagated for use in gene targeting procedures. Again the present invention is novel because differentiated cell types are used. The present invention is advantageous because the cells can be easily propagated, genetically modified and selected in vitro.

20 Other reported cloning methods (e.g., Wilmut et al, 1997) have relied on the use of serum starved cells. In the present invention, however, the donor cells are not in a state of serum starvation. According to Wilmut et al (1997), serum starved cells are quiescent, i.e., exiting the growth phase. Other methods (chemical, temperature, etc.) are also capable of producing
25 quiescent cells. The donor cells used in the present invention are not quiescent.

Suitable mammalian sources for oocytes include sheep, cows, pigs, goats, horses, rabbits, guinea pigs, mice, hamsters, rats, primates, etc. Preferably, the oocytes will be obtained from ungulates, and most

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preferably bovine.

Methods for isolation of oocytes are well known in the art. Essentially, this will comprise isolating oocytes from the ovaries or reproductive tract of a mammal, e.g., a bovine. A readily available source
5 of bovine oocytes is slaughterhouse materials.

For the successful use of techniques such as genetic engineering, nuclear transfer and cloning, oocytes must generally be matured *in vitro* before these cells may be used as recipient cells for nuclear transfer, and before they can be fertilized by the sperm cell to develop into an embryo.
10 This process generally requires collecting immature (prophase I) oocytes from mammalian ovaries, e.g., bovine ovaries obtained at a slaughterhouse, and maturing the oocytes in a maturation medium prior to fertilization or enucleation until the oocyte attains the metaphase II stage, which in the case of bovine oocytes generally occurs about 18-24 hours post-aspiration.
15 For purposes of the present invention, this period of time is known as the "maturation period." As used herein for calculation of time periods, "aspiration" refers to aspiration of the immature oocyte from ovarian follicles.

Additionally, metaphase II stage oocytes, which have been matured
20 *in vivo* have been successfully used in nuclear transfer techniques. Essentially, mature metaphase II oocytes are collected surgically from either non-superovulated or superovulated cows or heifers 35 to 48 hours past the onset of estrus or past the injection of human chorionic gonadotropin (hCG) or similar hormone.

25 The stage of maturation of the oocyte at enucleation and nuclear transfer has been reported to be significant to the success of NT methods. (See e.g., Prather et al., *Differentiation*, 48, 1-8, 1991). In general, successful mammalian embryo cloning practices use the metaphase II stage oocyte as the recipient oocyte because at this stage it is believed that

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the oocyte can be or is sufficiently "activated" to treat the introduced nucleus as it does a fertilizing sperm. In domestic animals, and especially cattle, the oocyte activation period generally ranges from about 16-52 hours, preferably about 28-42 hours post-aspiration.

5 For example, immature oocytes may be washed in HEPES buffered hamster embryo culture medium (HECM) as described in Seshagine et al., *Biol. Reprod.*, 40, 544-606, 1989, and then placed into drops of maturation medium consisting of 50 microliters of tissue culture medium (TCM) 199 containing 10% fetal calf serum which contains appropriate gonadotropins
10 such as luteinizing hormone (LH) and follicle stimulating hormone (FSH), and estradiol under a layer of lightweight paraffin or silicon at 39°C.

 After a fixed time maturation period, which ranges from about 10 to 40 hours, and preferably about 16-18 hours, the oocytes will be enucleated. Prior to enucleation the oocytes will preferably be removed and
15 placed in HECM containing 1 milligram per milliliter of hyaluronidase prior to removal of cumulus cells. This may be effected by repeated pipetting through very fine bore pipettes or by vortexing briefly. The stripped oocytes are then screened for polar bodies, and the selected metaphase II oocytes, as determined by the presence of polar bodies, are then used for
20 nuclear transfer. Enucleation follows.

 Enucleation may be effected by known methods, such as described in U.S. Patent No. 4,994,384 which is incorporated by reference herein. For example, metaphase II oocytes are either placed in HECM, optionally containing 7.5 micrograms per milliliter cytochalasin B, for immediate
25 enucleation, or may be placed in a suitable medium, for example an embryo culture medium such as CR1aa, plus 10% estrus cow serum, and then enucleated later, preferably not more than 24 hours later, and more preferably 16-18 hours later.

 Enucleation may be accomplished microsurgically using a

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micropipette to remove the polar body and the adjacent cytoplasm. The oocytes may then be screened to identify those of which have been successfully enucleated. This screening may be effected by staining the oocytes with 1 microgram per milliliter 33342 Hoechst dye in HECM, and
5 then viewing the oocytes under ultraviolet irradiation for less than 10 seconds. The oocytes that have been successfully enucleated can then be placed in a suitable culture medium, e.g., CR1aa plus 10% serum.

In the present invention, the recipient oocytes will preferably be enucleated at a time ranging from about 10 hours to about 40 hours after
10 the initiation of *in vitro* maturation, more preferably from about 16 hours to about 24 hours after initiation of *in vitro* maturation, and most preferably about 16-18 hours after initiation of *in vitro* maturation.

A single mammalian cell of the same species as the enucleated oocyte will then be transferred into the perivitelline space of the enucleated
15 oocyte used to produce the NT unit. The mammalian cell and the enucleated oocyte will be used to produce NT units according to methods known in the art. For example, the cells may be fused by electrofusion. Electrofusion is accomplished by providing a pulse of electricity that is sufficient to cause a transient breakdown of the plasma membrane. This
20 breakdown of the plasma membrane is very short because the membrane reforms rapidly. Thus, if two adjacent membranes are induced to breakdown and upon reformation the lipid bilayers intermingle, small channels will open between the two cells. Due to the thermodynamic instability of such a small opening, it enlarges until the two cells become
25 one. Reference is made to U.S. Patent 4,997,384 by Prather et al., (incorporated by reference in its entirety herein) for a further discussion of this process. A variety of electrofusion media can be used including e.g., sucrose, mannitol, sorbitol and phosphate buffered solution. Fusion can also be accomplished using Sendai virus as a fusogenic agent (Graham,

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Wister Inot. Symp. Monogr., 9, 19, 1969).

Also, in some cases (e.g. with small donor nuclei) it may be preferable to inject the nucleus directly into the oocyte rather than using electroporation fusion. Such techniques are disclosed in Collas and Barnes, 5 *Mol. Reprod. Dev.*, 38:264-267 (1994), incorporated by reference in its entirety herein.

Preferably, the mammalian cell and oocyte are electrofused in a 500 μm chamber containing fusion medium (0.25 M D-sorbitol, 100 μM calcium acetate, 0.5 mM magnesium acetate, 1.0 g/l BSA (fatty acid free), pH 7.2) 10 by application of an electrical pulse of 90-120V for about 15 μsec , about 24 hours after initiation of oocyte maturation. After fusion, the resultant fused NT units are then placed in a suitable medium until activation, e.g., CR1aa medium. Typically activation will be effected shortly thereafter, typically less than 24 hours later, and preferably about 2-9 hours later.

15 The NT unit may be activated by known methods. Such methods include, e.g., culturing the NT unit at sub-physiological temperature, in essence by applying a cold, or actually cool temperature shock to the NT unit. This may be most conveniently done by culturing the NT unit at room temperature, which is cold relative to the physiological temperature 20 conditions to which embryos are normally exposed.

Alternatively, activation may be achieved by application of known activation agents. For example, penetration of oocytes by sperm during fertilization has been shown to activate prefusion oocytes to yield greater numbers of viable pregnancies and multiple genetically identical calves after 25 nuclear transfer. Also, treatments such as electrical and chemical shock may be used to activate NT embryos after fusion. Suitable oocyte activation methods are the subject of U.S. Patent No. 5,496,720, to Susko-Parrish et al., herein incorporated by reference in its entirety.

Additionally, activation may be effected by simultaneously or

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sequentially:

- (i) increasing levels of divalent cations in the oocyte, and
- (ii) reducing phosphorylation of cellular proteins in the oocyte.

This will generally be effected by introducing divalent cations into the
5 oocyte cytoplasm, e.g., magnesium, strontium, barium or calcium, e.g., in
the form of an ionophore. Other methods of increasing divalent cation
levels include the use of electric shock, treatment with ethanol and
treatment with caged chelators.

Phosphorylation may be reduced by known methods, e.g., by the
10 addition of kinase inhibitors, e.g., serine-threonine kinase inhibitors, such as
6-dimethylaminopurine, staurosporine, 2-aminopurine, and sphingosine.

Alternatively, phosphorylation of cellular proteins may be inhibited by
introduction of a phosphatase into the oocyte, e.g., phosphatase 2A and
phosphatase 2B.

15 In one embodiment, NT activation is effected by briefly exposing the
fused NT unit to a TL-HEPES medium containing 5 μ M ionomycin and 1
mg/ml BSA, followed by washing in TL-HEPES containing 30 mg/ml BSA
within about 24 hours after fusion, and preferably about 2 to 9 hours after
fusion.

20 The activated NT units may then be cultured in a suitable *in vitro*
culture medium until the generation of CICM cells and cell colonies. Culture
media suitable for culturing and maturation of embryos are well known in
the art. Examples of known media, which may be used for bovine embryo
culture and maintenance, include Ham's F-10 + 10% fetal calf serum
25 (FCS), Tissue Culture Medium-199 (TCM-199) + 10% fetal calf serum,
Tyrodes-Albumin-Lactate-Pyruvate (TALP), Dulbecco's Phosphate Buffered
Saline (PBS), Eagle's and Whitten's media. One of the most common
media used for the collection and maturation of oocytes is TCM-199, and 1
to 20% serum supplement including fetal calf serum, newborn serum,

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estruual cow serum, lamb serum or steer serum. A preferred maintenance medium includes TCM-199 with Earl salts, 10% fetal calf serum, 0.2 mM Na pyruvate and 50 μ g/ml gentamicin sulphate. Any of the above may also involve co-culture with a variety of cell types such as granulosa cells, oviduct cells, BRL cells and uterine cells and STO cells.

Another maintenance medium is described in U.S. Patent 5,096,822 to Rosenkrans, Jr. et al., which is incorporated herein by reference. This embryo medium, named CR1, contains the nutritional substances necessary to support an embryo.

CR1 contains hemicalcium L-lactate in amounts ranging from 1.0 mM to 10 mM, preferably 1.0 mM to 5.0 mM. Hemicalcium L-lactate is L-lactate with a hemicalcium salt incorporated thereon. Hemicalcium L-lactate is significant in that a single component satisfies two major requirements in the culture medium: (i) the calcium requirement necessary for compaction and cytoskeleton arrangement; and (ii) the lactate requirement necessary for metabolism and electron transport. Hemicalcium L-lactate also serves as valuable mineral and energy source for the medium necessary for viability of the embryos.

Advantageously, CR1 medium does not contain serum, such as fetal calf serum, and does not require the use of a co-culture of animal cells or other biological media, i.e., media comprising animal cells such as oviductal cells. Biological media can sometimes be disadvantageous in that they may contain microorganisms or trace factors which may be harmful to the embryos and which are difficult to detect, characterize and eliminate.

Examples of the main components in CR1 medium include hemicalcium L-lactate, sodium chloride, potassium chloride, sodium bicarbonate and a minor amount of fatty-acid free bovine serum albumin (Sigma A-6003). Additionally, a defined quantity of essential and non-essential amino acids may be added to the medium. CR1 with amino acids

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is known by the abbreviation "CR1aa."

CR1 medium preferably contains the following components in the following quantities:

	sodium chloride	- 114.7 mM
5	potassium chloride	- 3.1 mM
	sodium bicarbonate	- 26.2 mM
	hemicalcium L-lactate	- 5 mM
	fatty-acid free BSA	- 3 mg/ml

In one embodiment, the activated NT embryos unit are placed in
10 CR1aa medium containing 1.9 mM DMAP for about 4 hours followed by a wash in HECM and then cultured in CR1aa containing BSA.

For example, the activated NT units may be transferred to CR1aa culture medium containing 2.0 mM DMAP (Sigma) and cultured under ambient conditions, e.g., about 38.5°C, 5% CO₂ for a suitable time, e.g.,
15 about 4 to 5 hours.

Afterward, the cultured NT unit or units are preferably washed and then placed in a suitable media, e.g., CR1aa medium containing 10% FCS and 6 mg/ml contained in well plates which preferably contain a suitable confluent feeder layer. Suitable feeder layers include, by way of example,
20 fibroblasts and epithelial cells, e.g., fibroblasts and uterine epithelial cells derived from ungulates, chicken fibroblasts, murine (e.g., mouse or rat) fibroblasts, STO and SI-m220 feeder cell lines, and BRL cells.

In one embodiment, the feeder cells comprise mouse embryonic fibroblasts. Preparation of a suitable fibroblast feeder layer is described in
25 the example which follows and is well within the skill of the ordinary artisan.

The NT units are cultured on the feeder layer (5×10^5 cells/ml) until the NT units reach a size suitable for transferring to a recipient female, or for obtaining cells which may be used to produce CICM cells or cell

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colonies. Preferably, these NT units will be cultured until at least about 2 to 400 cells, more preferably about 4 to 128 cells, and most preferably at least about 50 cells. The culturing will be effected under suitable conditions, i.e., about 38.5°C and 5% CO₂, with the culture medium
5 changed in order to optimize growth typically about every 2-5 days, preferably about every 3 days.

The methods for embryo transfer and recipient animal management in the present invention are standard procedures used in the embryo transfer industry. Synchronous transfers are important for success of the present
10 invention, i.e., the stage of the NT embryo is in synchrony with the estrus cycle of the recipient female. This advantage and how to maintain recipients are reviewed in Siedel, G.E., Jr. ("Critical review of embryo transfer procedures with cattle" in Fertilization and Embryonic Development in Vitro (1981) L. Mastroianni, Jr. and J.D. Biggers, ed., Plenum Press,
15 New York, NY, page 323), the contents of which are hereby incorporated by reference.

By the present invention, cloning efficiency using nuclei donated from adult cells may be the same as when using nuclei from fetal cells. For example, the efficiency of development to morula and blastocyst stage
20 embryos is the same whether using nuclei from fetal or adult cow cells.

The present invention can also be used to clone genetically engineered or transgenic mammals. As explained above, the present invention is advantageous in that transgenic procedures can be simplified by working with a differentiated cell source that can be clonally propagated.
25 In particular, the differentiated cells used for donor nuclei have a desired DNA sequence inserted, removed or modified. Those genetically altered, differentiated cells are then used for nuclear transplantation with enucleated oocytes.

Any known method for inserting, deleting or modifying a desired

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DNA sequence from a mammalian cell may be used for altering the differentiated cell to be used as the nuclear donor. These procedures may remove all or part of a DNA sequence, and the DNA sequence may be heterologous. Included is the technique of homologous recombination, which allows the insertion, deletion or modification of a DNA sequence or sequences at a specific site or sites in the cell genome.

The present invention can thus be used to provide adult mammals with desired genotypes. Multiplication of adult ungulates with proven genetic superiority or other desirable traits is particularly useful, including transgenic or genetically engineered animals, and chimeric animals. Furthermore, cells and tissues from the NT fetus, including transgenic and/or chimeric fetuses, can be used in cell, tissue and organ transplantation for the treatment of numerous diseases as described below in connection with the use of CICM cells.

For production of CICM cells and cell lines, after NT units of the desired size are obtained, the cells are mechanically removed from the zone and are then used. This is preferably effected by taking the clump of cells which comprise the NT unit, which typically will contain at least about 50 cells, washing such cells, and plating the cells onto a feeder layer, e.g., irradiated fibroblast cells. Typically, the cells used to obtain the stem cells or cell colonies will be obtained from the inner most portion of the cultured NT unit which is preferably at least 50 cells in size. However, NT units of smaller or greater cell numbers as well as cells from other portions of the NT unit may also be used to obtain ES cells and cell colonies. The cells are maintained in the feeder layer in a suitable growth medium, e.g., alpha MEM supplemented with 10% FCS and 0.1 mM β -mercaptoethanol (Sigma) and L-glutamine. The growth medium is changed as often as necessary to optimize growth, e.g., about every 2-3 days.

This culturing process results in the formation of CICM cells or cell

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lines. One skilled in the art can vary the culturing conditions as desired to optimize growth of the particular CICM cells. Also, genetically engineered or transgenic mammalian CICM cells may be produced according to the present invention. That is, the methods described above can be used to produce NT units in which a desired DNA sequence or sequences have been introduced, or from which all or part of an endogenous DNA sequence or sequences have been removed or modified. Those genetically engineered or transgenic NT units can then be used to produce genetically engineered or transgenic CICM cells, including human cells.

10 The resultant CICM cells and cell lines, preferably human CICM cells and cell lines, have numerous therapeutic and diagnostic applications. Most especially, such CICM cells may be used for cell transplantation therapies. Human CICM cells have application in the treatment of numerous disease conditions. Human NT units *per se* may also be used in the treatment of disease conditions.

15 In this regard, it is known that mouse embryonic stem (ES) cells are capable of differentiating into almost any cell type, e.g., hematopoietic stem cells. Therefore, human CICM cells produced according to the invention should possess similar differentiation capacity. The CICM cells according to the invention will be induced to differentiate to obtain the desired cell types according to known methods. For example, the subject human CICM cells may be induced to differentiate into hematopoietic stem cells, nerve cells, muscle cells, cardiac muscle cells, liver cells, cartilage cells, epithelial cells, urinary tract cells, etc., by culturing such cells in differentiation medium and under conditions which provide for cell differentiation. Medium and methods which result in the differentiation of CICM cells are known in the art as are suitable culturing conditions.

25 For example, Palacios et al, *Proc. Natl. Acad. Sci., USA*, 92:7530-7537 (1995) teaches the production of hematopoietic stem cells from an

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embryonic cell line by subjecting stem cells to an induction procedure comprising initially culturing aggregates of such cells in a suspension culture medium lacking retinoic acid followed by culturing in the same medium containing retinoic acid, followed by transferral of cell aggregates
5 to a substrate which provides for cell attachment.

Moreover, Pedersen, *J. Reprod. Fertil. Dev.*, 6:543-552 (1994) is a review article which references numerous articles disclosing methods for *in vitro* differentiation of embryonic stem cells to produce various differentiated cell types including hematopoietic cells, muscle, cardiac
10 muscle, nerve cells, among others.

Further, Bain et al, *Dev. Biol.*, 168:342-357 (1995) teaches *in vitro* differentiation of embryonic stem cells to produce neural cells which possess neuronal properties. These references are exemplary of reported methods for obtaining differentiated cells from embryonic or stem cells.
15 These references and in particular the disclosures therein relating to methods for differentiating embryonic stem cells are incorporated by reference in their entirety herein.

Thus, using known methods and culture medium, one skilled in the art may culture the subject CICM cells, including genetically engineered or
20 transgenic CICM cells, to obtain desired differentiated cell types, e.g., neural cells, muscle cells, hematopoietic cells, etc.

The subject CICM cells may be used to obtain any desired differentiated cell type. Therapeutic usages of such differentiated human cells are unparalleled. For example, human hematopoietic stem cells may
25 be used in medical treatments requiring bone marrow transplantation. Such procedures are used to treat many diseases, e.g., late stage cancers such as ovarian cancer and leukemia, as well as diseases that compromise the immune system, such as AIDS. Hematopoietic stem cells can be obtained, e.g., by fusing adult somatic cells of a cancer or AIDS patient, e.g.,

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epithelial cells or lymphocytes with an enucleated oocyte, obtaining CICM cells as described above, and culturing such cells under conditions which favor differentiation, until hematopoietic stem cells are obtained. Such hematopoietic cells may be used in the treatment of diseases including
5 cancer and AIDS.

Alternatively, adult somatic cells from a patient with a neurological disorder may be fused with an enucleated oocyte, human CICM cells obtained therefrom, and such cells cultured under differentiation conditions to produce neural cell lines. Specific diseases treatable by transplantation
10 of such human neural cells include, by way of example, Parkinson's disease, Alzheimer's disease, ALS and cerebral palsy, among others. In the specific case of Parkinson's disease, it has been demonstrated that transplanted fetal brain neural cells make the proper connections with surrounding cells and produce dopamine. This can result in long-term
15 reversal of Parkinson's disease symptoms.

The great advantage of the subject invention is that it provides an essentially limitless supply of isogenic or syngenic human cells suitable for transplantation. Therefore, it will obviate the significant problem associated with current transplantation methods, i.e., rejection of the transplanted
20 tissue which may occur because of host-vs-graft or graft-vs-host rejection. Conventionally, rejection is prevented or reduced by the administration of anti-rejection drugs such as cyclosporine. However, such drugs have significant adverse side-effects, e.g., immunosuppression, carcinogenic properties, as well as being very expensive. The present invention should
25 eliminate, or at least greatly reduce, the need for anti-rejection drugs.

Other diseases and conditions treatable by isogenic cell therapy include, by way of example, spinal cord injuries, multiple sclerosis, muscular dystrophy, diabetes, liver diseases, i.e., hypercholesterolemia, heart diseases, cartilage replacement, burns, foot ulcers, gastrointestinal

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diseases, vascular diseases, kidney disease, urinary tract disease, and aging related diseases and conditions.

This methodology can be used to replace defective genes, e.g., defective immune system genes, cystic fibrosis genes, or to introduce genes which result in the expression of therapeutically beneficial proteins such as growth factors, lymphokines, cytokines, enzymes, etc. For example, the DNA sequence encoding brain derived growth factor may be introduced into human CICM cells, the cells differentiated into neural cells and the cells transplanted into a Parkinson's patient to retard the loss of neural cells during such disease.

Previously, cell types transfected with BDNF varied from primary cells to immortalized cell lines, either neural or non-neural (myoblast and fibroblast) derived cells. For example, astrocytes have been transfected with BDNF gene using retroviral vectors, and the cells grafted into a rat model of Parkinson's disease (Yoshimoto et al., *Brain Research*, 691:25-36, (1995)).

This *ex vivo* therapy reduced Parkinson's-like symptoms in the rats up to 45% 32 days after transfer. Also, the tyrosine hydroxylase gene has been placed into astrocytes with similar results (Lundberg et al., *Develop. Neurol.*, 139:39-53 (1996) and references cited therein).

However, such *ex vivo* systems have problems. In particular, retroviral vectors currently used are down-regulated *in vivo* and the transgene is only transiently expressed (review by Mulligan, *Science*, 260:926-932 (1993)). Also, such studies used primary cells, astrocytes, which have finite life span and replicate slowly. Such properties adversely affect the rate of transfection and impede selection of stably transfected cells. Moreover, it is almost impossible to propagate a large population of gene targeted primary cells to be used in homologous recombination techniques. By contrast, the difficulties associated with retroviral systems

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should be eliminated by the use of mammalian cloning using differentiated cells and CICM cells.

DNA sequences which may be introduced into the subject CICM or differentiated cells include, by way of example, those which encode
5 epidermal growth factor, basic fibroblast growth factor, glial derived neurotrophic growth factor, insulin-like growth factor (I and II), neurotrophin-3, neurotrophin-4/5, ciliary neurotrophic factor, AFT-1, cytokines (interleukins, interferons, colony stimulating factors, tumor necrosis factors (alpha and beta), etc.), therapeutic enzymes, etc.

10 In addition to the use of human NT units and CICM cells in cell, tissue and organ transplantation, the present invention also includes the use of non-human cells in the treatment of human diseases. Thus, CICM cells, NT fetuses and NT and chimeric offspring (transgenic or non-transgenic) of any species may be used in the treatment of human disease conditions
15 where cell, tissue or organ transplantation is warranted. In general, CICM cell, fetuses and offspring according to the present invention can be used within the same species (autologous, syngenic or allografts) or across species (xenografts). For example, brain cells from bovine NT fetuses may be used to treat Parkinson's disease.

20 Also, the subject CICM cells, preferably human cells, may be used as an *in vitro* model of differentiation, in particular for the study of genes which are involved in the regulation of early development. Also, differentiated cell tissues and organs using the subject CICM cells may be used in drug studies.

25 Further, the subject CICM cells may be used as nuclear donors for the production of other CICM cells and cell colonies.

In order to more clearly describe the subject invention, the following examples are provided.

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EXAMPLE 1

Isolation of primary cultures of bovine and porcine embryonic and adult bovine fibroblast cells.

- 5 Primary cultures of bovine and porcine fibroblasts were obtained from fetuses (45 days of pregnancy for cattle and 35 days for pig fetuses). The head, liver, heart and alimentary tract were aseptically removed, the fetuses minced and incubated for 30 minutes at 37°C in prewarmed trypsin EDTA solution (0.05% trypsin/0.02% EDTA; GIBCO, Grand Island, NY).
- 10 Fibroblast cells were plated in tissue culture dishes and cultured in alpha-MEM, medium (BioWhittaker, Walkersville, MD) supplemented with 10% fetal calf serum (FCS) (Hyclone, Logen, UT), penicillin (100 IU/ml) and streptomycin (50 μ l/ml). The fibroblasts were grown and maintained in a humidified atmosphere with 5% CO₂ in air at 37°C. Cells were passaged
- 15 regularly upon reaching confluency.

- Adult fibroblast cells were isolated from the lung and skin of a cow (approximately five years of age). Minced lung tissue was incubated overnight at 10°C in trypsin EDTA solution (0.05% trypsin/0.02% EDTA; GIBCO, Grand Island, NY). The following day tissue and any disassociated
- 20 cells were incubated for one hour at 37°C in prewarmed trypsin EDTA solution (0.05% trypsin/0.02% EDTA; GIBCO, Grand Island, NY) and processed through three consecutive washes and trypsin incubations (one hr). Fibroblast cells were plated in tissue culture dishes and cultured in alpha-MEM medium (BioWhittaker, Walkersville, MD) supplemented with

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time in development, ranging from approximately post embryonic disc stage through adult life of the animal (bovine day 12 to 15 after fertilization to 10 to 15 years of age animals). This procedure can also be used to isolate fibroblasts from other mammals, including mice.

5 **Introduction of a marker gene (foreign heterologous DNA) into embryonic and adult fibroblast cells.**

The following electroporation procedure was conducted for both embryonic (cattle and pigs) and adult (cattle) fibroblast cells. Standard
10 microinjection procedures may also be used to introduce heterologous DNA into fibroblast cells, however, in this example electroporation was used because it is an easier procedure.

Culture plates containing propagating fibroblast cells were incubated in trypsin EDTA solution (0.05% trypsin/0.02% EDTA; GIBCO, Grand
15 Island, NY) until the cells were in a single cell suspension. The cells were spun down at 500 x g and re-suspended at 5 million cells per ml with phosphate buffered saline (PBS).

The reporter gene construct contained the cytomegalovirus promoter and the beta-galactosidase, neomycin phosphotransferase fusion gene
20 (beta-GEO). The reporter gene and the cells at 50 μ g/ml final concentration were added to the electroporation chamber. After the electroporation pulse, the fibroblast cells were transferred back into the growth medium (alpha-MEM medium (BioWhittaker, Walkersville, MD) supplemented with 10% fetal calf serum (FCS) (Hyclone, Logan, UT), penicillin (100 IU/ml) and
25 streptomycin (50 μ l/ml)).

The day after electroporation, attached fibroblast cells were selected for stable integration of the reporter gene. G418 (400 μ g/ml) was added to growth medium for 15 days (range: 3 days until the end of the cultured cells' life span). This drug kills any cells without the beta-GEO gene, since
30 they do not express the neo resistance gene. At the end of this time,

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colonies of stable transgenic cells were present. Each colony was propagated independently of each other. Transgenic fibroblast cells were stained with X-gal to observe expression of beta-galactosidase, and confirmed positive for integration using PCR amplification of the beta-GEO gene and run out on an agarose gel.

Use of transgenic fibroblast cells in nuclear transfer procedures to create CICM cell lines and transgenic fetuses

One line of cells (CL-1) derived from one colony of bovine embryonic fibroblast cells was used as donor nuclei in the nuclear transfer (NT) procedure. General NT procedures are described above.

Slaughterhouse oocytes were matured in vitro. The oocytes were stripped of cumulus cells and enucleated with a beveled micropipette at approximately 18 to 20 hrs post maturation (hpm). Enucleation was confirmed in TL-HEPES medium plus Hoechst 33342 (3 μ g/ml; Sigma). Individual donor cells (fibroblasts) were then placed in the perivitelline space of the recipient oocyte. The bovine oocyte cytoplasm and the donor nucleus (NT unit) were fused together using electrofusion techniques. One fusion pulse consisting of 120 V for 15 μ sec in a 500 μ m gap chamber filled with fusion medium was applied to the NT unit. This occurred at 24 hpm. The NT units were placed in CR1aa medium until 26 to 27 hpm.

The general procedure used to artificially activate oocytes has been described above. NT unit activation was initiated between 26 and 27 hpm. Briefly, NT units were exposed for four min to ionomycin (5 μ M; CalBiochem, La Jolla, CA) in TL-HEPES supplemented with 1 mg/ml BSA and then washed for five min in TL-HEPES supplemented with 30 mg/ml BSA. Throughout the ionomycin treatment, NT units were also exposed to 2 mM DMAP (Sigma). Following the wash, NT units were then transferred into a microdrop of CR1aa culture medium containing 2 mM DMAP (Sigma)

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and cultured at 38.5°C 5% CO₂ for four to five hrs. The embryos were washed and then placed in CR1aa medium plus 10% FCS and 6 mg/ml BSA in four well plates containing a confluent feeder layer of mouse embryonic fibroblast. The NT units were cultured for three more days at 38.5°C and 5% CO₂. Culture medium was changed every three days until days 5 to 8 after activation. At this time blastocyst stage NT embryos can be used to produce transgenic CICM (cultured inner cell mass) cell lines or fetuses. The inner cell mass of these NT units can be isolated and plated on a feeder layer. Also, NT units were transferred into recipient females. The pregnancies were aborted between 35-48 days of gestation. This resulted in seven cloned transgenic fetuses having the beta-GEO gene in all tissues checked. Six of the seven embryos had a normal heart beat detected via ultrasound observation. Also, histological sections of fetuses showed no overt anomalies. Thus, this is a fast and easy method of making transgenic CICM cell lines and fetuses. This procedure is generally conducive to gene targeted CICM cell lines and fetuses.

The table below summarizes the results of these experiments.

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Donor cell type	n	Cleavage (%)	Blastocysts (%)	CICM* lines (%)	Recovered transgenic fetuses (%)	Ongoing pregnancies past 40 days
CL-1 bovine fetal fibroblast (bGEO)	412	220 (53%)	40 (10%)	22 (55%)	N/A	N/A
CL-1 bovine fetal fibroblast (bGEO)	362 5	2127 (59%)	46 (9%)	N/A	7 fetuses†	8‡
CICM cell line derived from CL-1 NT embryos	709		5 (0.7%)	N/A	0	0
Adult bovine fibroblast	215	119 (55%)	20 (9%)	N/A	N/A	N/A

* 19 lines were positive for beta-GEO, 2 were negative and one line died prior to PCR detection.

† One fetus was dead and another was slightly retarded in development at 35 days of gestation. Five fetuses recovered between 38 to 45 days were normal. All fetuses were confirmed transgenic.

‡ First offspring to be born October, 1997.

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EXAMPLE 2

Chimeric fetuses and offspring derived from transgenic CICM cells. The transgenic CICM cell line was derived originally from a transgenic NT unit (differentiated cell).

5 A CICM line derived from transgenic NT embryos (a CL-1 cell transferred into an enucleated oocyte) was used to produce chimeric embryos and fetuses. Colonies of transgenic CICM cells were disaggregated either using 1-5 mg/ml pronase or 0.05% trypsin/EDTA combined with mechanical disaggregation methods so that clumps of five
10 or fewer cells were produced. Trypsin or pronase activity was inactivated by passing the cells through multiple washes of 30 to 100% fetal calf serum. The disaggregated cells were placed in micromanipulation plates containing TL-HEPES medium. Fertilized embryos were also placed in these plates and micromanipulation tools were used to produce the chimeric
15 embryos. Eight to ten transgenic CICM cells were injected into 8-16 cell stage fertilized embryos. These embryos were cultured in vitro to the blastocyst stage and then transferred into recipient animals.

 A total of 6 blastocyst stage chimeric embryos were non-surgically transferred into two recipient females. After five weeks of gestation 3
20 fetuses were recovered. Several tissues of the three fetuses, including germ cells of the gonad (suggesting germ-line chimeras), were screened by PCR amplification and southern blot hybridization of the amplified product to a beta-galactosidase fragment. Of the three fetuses, two were positive for contribution from the transgenic CICM cells. Both of these fetuses had
25 transgenic CICM contribution to the gonad.

 Ten chimeric embryos were allowed to go to term, and 7 of the 10 developed to offspring. Ear notches were taken and DNA isolated from each calf. Upon PCR amplification, one of the seven was confirmed to be a transgenic chimeric offspring.

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Transgenic NT embryos derived from transgenic CICM cell lines. The transgenic CICM cell line was derived originally from a transgenic NT unit (differentiated cell).

The same transgenic CICM cell lines were used to produce NT 5 embryos. The NT procedures described in Example 1 were used except that CICM cells instead of fibroblast cells were used as the donor cell fused with the enucleated oocyte. Colonies of transgenic CICM cells were disaggregated either using 1-5 mg/ml pronase or 0.05% trypsin/EDTA combined with mechanical disaggregation methods so that clumps of five 10 or fewer cells were produced. Trypsin or pronase activity was inactivated by passing the cells through multiple washes of 30 to 100% fetal calf serum before transferring the cells into enucleated oocytes. Results are reported in Table 1 (third group). Five blastocyst stage embryos were produced.

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WHAT IS CLAIMED IS:

1. A method of cloning a mammal, comprising:
 - (i) inserting a desired non-serum starved, differentiated mammalian cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated cell or cell nucleus, under conditions suitable for the formation of a nuclear transfer (NT) unit;
 - (ii) activating the resultant nuclear transfer unit; and
 - (iii) transferring said cultured NT unit to a host mammal such that the NT unit develops into a fetus.
2. The method according to claim 1, which further comprises developing the fetus to an offspring.
3. The method according to claim 1, wherein a desired DNA is inserted, removed or modified in said differentiated mammalian cell or cell nucleus, thereby resulting in the production of a genetically altered NT unit.
4. The method according to claim 3, which further comprises developing the fetus to an offspring.
5. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is derived from mesoderm lineage.
6. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is derived from ectoderm lineage.
7. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is derived from endoderm lineage.

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8. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is a fibroblast cell or cell nucleus.

9. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is from an ungulate.

5 10. The method according to claim 9, wherein the ungulate is selected from the group consisting of bovine, ovine, porcine, equine, caprine and buffalo.

11. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is an adult cell or cell nucleus.

10 12. The method according to claim 1, wherein the differentiated mammalian cell or cell nucleus is an embryonic or fetal cell or cell nucleus.

13. The method according to claim 1, wherein the enucleated oocyte is matured prior to enucleation.

15 14. The method according to claim 1, wherein the fused nuclear transfer unit is activated by exposure to ionomycin and 6-dimethylaminopurine.

15. The method according to claim 3, wherein microinjection is used to insert a heterologous DNA.

20 16. The method according to claim 3, wherein electroporation is used to insert a heterologous DNA.

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17. A fetus obtained according to the method of claim 1.

18. An offspring obtained according to the method of claim 2.

19. Progeny of the offspring according to claim 18.

20. A transgenic fetus obtained according to the method of claim

5 3.

21. A transgenic offspring obtained according to the method of
claim 4.

22. Progeny of the offspring according to claim 21.

23. The method according to claim 1, which further comprises
10 combining the cloned NT unit with a fertilized embryo to produce a chimeric
embryo.

24. The method according to claim 23, which further comprises
developing the fetus to an offspring.

25. A fetus obtained according to the method of claim 23.

15 26. An offspring obtained according to the method of claim 24.

27. Progeny of the mammal according to claim 26.

28. The method according to claim 1, wherein said activated nuclear
transfer unit is cultured until greater than the 2-cell developmental stage.

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29. A method of producing a CICM cell line, comprising:
- (i) inserting a desired non-serum starved, differentiated mammalian cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated cell or cell nucleus, under conditions suitable for the formation of a nuclear transfer (NT) unit;
 - (ii) activating the resultant nuclear transfer unit; and
 - (i11) culturing cells obtained from said cultured NT unit to obtain a CICM cell line.

30. The method according to claim 29, wherein said activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

31. A CICM cell line obtained according to the method of claim 29.

32. The method according to claim 29, wherein a desired DNA is inserted, removed or modified in said differentiated mammalian cell or cell nucleus, thereby resulting in the production of a genetically altered NT unit.

33. A transgenic CICM cell line obtained according to claim 32.

34. The method of claim 29, wherein the resultant CICM cell line is induced to differentiate.

35. Differentiated cells obtained by the method of claim 34.

36. Human differentiated cells obtained by the method of claim 34.

37. A method of therapy which comprises administering to a

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patient in need of cell transplantation therapy isogenic differentiated cells according to claim 36.

38. The method of Claim 37, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

39. A method of therapy which comprises administering to a human patient in need of cell transplantation therapy xenogenic differentiated cells according to claim 35.

40. The method according to claim 39 wherein the xenogenic differentiated cells are bovine cells.

41. The method of Claim 39, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

42. The method of Claim 37, wherein the differentiated human cells are hematopoietic cells or neural cells.

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43. The method of Claim 37, wherein the therapy is for treatment of Parkinson's disease and the differentiated cells are neural cells.

44. The method of Claim 37, wherein the therapy is for the treatment of cancer and the differentiated cells are hematopoietic cells.

5 45. A method of therapy which comprises administering to a human patient in need of cell transplantation therapy xenogenic cells obtained from a fetus according to claim 17.

46. The method according to claim 45 wherein the xenogenic cells are bovine cells.

10 47. The method of Claim 45, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage
15 defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

48. The method of claim 46 wherein said cell transplantation therapy is effected to treat Parkinson's disease.

20 49. A method of therapy which comprises administering to a human patient in need of cell transplantation therapy xenogenic cells obtained from an offspring according to claim 18.

50. The method according to claim 49 wherein the xenogenic cells

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are bovine cells.

51. The method of Claim 49, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

52. A method of therapy which comprises administering to a human patient in need of cell transplantation therapy xenogenic transgenic cells obtained from a transgenic fetus according to claim 20.

53. The method according to claim 52 wherein the xenogenic transgenic cells are bovine cells.

54. The method of Claim 52, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

55. The method of claim 53 wherein said cell transplantation therapy is effected to treat Parkinson's disease.

56. A method of therapy which comprises administering to a

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human patient in need of cell transplantation therapy xenogenic transgenic cells obtained from a transgenic offspring according to claim 21.

57. The method according to claim 56 wherein the xenogenic transgenic cells are bovine cells.

5 58. The method of Claim 56, wherein said cell transplantation therapy is effected to treat a disease or condition selected from the group consisting of Parkinson's disease, Huntington's disease, Alzheimer's disease, ALS, spinal cord defects or injuries, multiple sclerosis, muscular dystrophy, cystic fibrosis, liver disease, diabetes, heart disease, cartilage
10 defects or injuries, burns, foot ulcers, vascular disease, urinary tract disease, AIDS and cancer.

59. The method according to claim 29, which further comprises combining the cloned NT unit with a fertilized embryo to produce a chimera.

15 60. The method according to claim 59, which further comprises developing the chimeric CICM cell line to a chimeric embryo.

61. A chimeric embryo obtained according to claim 60.

62. The method according to claim 60, which further comprises developing the chimeric embryo to a chimeric fetus.

63. A chimeric fetus obtained according to claim 62.

20 64. The method according to claim 62, which further comprises developing the chimeric fetus to a chimeric offspring.

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65. A chimeric offspring obtained according to claim 64.

66. The method according to claim 59, wherein a desired DNA is inserted, removed or modified in said differentiated mammalian cell or cell nucleus, thereby resulting in the production of a genetically altered NT unit.

5 67. The method according to claim 66, which further comprises developing the chimeric CICM cell line to a chimeric embryo.

68. A chimeric embryo obtained according to claim 67.

69. The method according to claim 67, which further comprises developing the chimeric embryo to a chimeric fetus.

10 70. A chimeric fetus obtained according to claim 69.

71. The method according to claim 69, which further comprises developing the chimeric fetus to a chimeric offspring.

72. A chimeric offspring obtained according to claim 71.

73. A method of cloning a mammal, comprising:

- 15 (i) inserting a desired non-serum starved, differentiated CICM cell or cell nucleus into an enucleated mammalian oocyte of the same species as the differentiated CICM cell or cell nucleus, under conditions suitable for the formation of a nuclear transfer (NT) unit;
- (ii) activating the resultant nuclear transfer unit; and
- 20 (iii) transferring said cultured NT unit to a host mammal such that the NT unit develops into a fetus.

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74. The method according to claim 73, wherein said activated nuclear transfer unit is cultured until greater than the 2-cell developmental stage.

5 75. The method according to claim 73, which further comprises developing the fetus to an offspring.

76. A fetus obtained according to the method of claim 73.

77. An offspring obtained according to the method of claim 75.

78. An organ for use as an organ xenograft, which is obtained from the offspring according to claim 18.

10 79. An organ for use as an organ xenograft, which is obtained from the offspring according to claim 21.

80. An organ for use as an organ xenograft, which is obtained from the offspring according to claim 26.

15 81. An organ for use as an organ xenograft, which is obtained from the offspring according to claim 72.

82. An organ for use as an organ xenograft, which is obtained from the offspring according to claim 77.

83. The method according to claim 13, wherein the enucleated oocyte is matured *in vitro*.

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84. The method according to claim 1, wherein activation occurs after formation of the NT unit.

85. The method according to claim 84, wherein activation occurs 4 hours or later after formation of the NT unit.

5 86. The method according to claim 1, wherein the NT unit is cocultured *in vitro* with helper cells in an undefined medium.

87. A method of producing a pharmaceutically active protein, comprising isolating a pharmaceutically active protein which is expressed by a transgenic offspring according to claim 21.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/12800

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61K 49/00; C12N 5/00, 15/00

US CL :424/93.21, 93.7; 800/8, 13

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/93.21, 93.7; 800/8, 13

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, CHEMICAL ABSTRACTS, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	TRAVIS, J. A. Fantastical Experiment: The Science Behind the Controversial Cloning of Dolly. Science News. 05 April 1997, Vol. 151, pages 214-215, see entire document.	1-83
Y	SOLTER, S. Lambing by Nuclear Transfer. Nature 07 March 1996, Vol. 380, pages 24-25, see entire document.	1-83
Y	SCHULTZ, R.M. Role of Chromatin Structure in Zygotic Gene Activation in the Mammalian Embryo. Seminars in Cell Biology. 1995, Vol. 6, pages 201-208, see especially page 206.	1-83

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/12800

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SIMS, M. et al. Production of Calves by Transfer of Nuclei from Cultured Inner Cell Mass Cells. Proceedings of the National Academy of Sciences (USA). June 1993, Vol. 90, pages 6143-6147, see entire document.	1-83
Y	ZWIEBEL, J.A. et al. Drug Delivery by Genetically Engineered Cell Implants. Annals of the New York Academy of Science. 1991, Vol. 618, pages 394-404, especially 400-402.	37-59
Y	KEEFER, C.L. et al. Bovine Inner Cell Mass Cells as Donor Nuclei in the Production of Nuclear Transfer Embryos and Calves. Biology of Reproduction. 1994, Vol. 50, pages 935-939, especially 936-938.	1-83
Y	YULL, F. et al. Fixing Human Factor IX (fIX): Correction of a Cryptic RNA Splice Enables the Production of Biologically Active fIX in the Mammary Gland of Transgenic Mice. Proceedings of the National Academy of Sciences. November 1995, Vol. 92, pages 10899-10903, see especially page 10902.	87